NOISE AND VIBRATION DIFFERENCES ON LAND AND AT SEA

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This paper is intended for those who have experience in dealing with noise and vibration on land installations, but who have not had direct shipboard experience. It does not pretend to give solutions to the many problems which may arise but, if it gives some guidance to the practitioner in his first contact with a marine application, its object will have been achieved.

Sources of noise and vibration

A ship, especially a large passenger liner, can be likened to a township in a tin can; it is completely self-supporting - at least for a couple of weeks - and, if adequate precautions are not taken, noise and vibration can be conveyed through the whole structure as effectively as a scandalous rumour. Even a large hotel or shopping complex will not normally generate all its own power supplies - and neither of these will be self-propelled!

The propulsion unit is generally a diesel engine direct coupled to the propeller or a steam turbine driving the propeller through speed-reducing gears. Numerous ships have a diesel engine with a normal running speed of about 150 rev/min and it is often supposed that there are no real problems in balancing such an engine, especially for first-order forces and couples. With land applications it can reasonably be assumed that a machine will be sitting on a rigid foundation and the conventional method of using force and couple polygons can be used for evaluating the balancing characteristics. A ship's hull must be regarded as a flexible beam and it is quite possible that one end of a main engine will be sitting on a vibrational node with the other end on an anti-node. In these circumstances it is necessary to consider a polygon composed of (force x hull displacement) vectors.

It is often asked why ships' main engines are not mounted on resilient mountings. If one considers the case where the engine is running at 150 rev/min it would be necessary to use mountings which had a stiffness equivalent to a deflexion of about one metre if first order forces are to be attenuated and even this would not take in to account the fact that these engines have to run at speeds down to about 50 rev/min. On an increasing number of ships medium-speed diesel engines running at about 600 rev/min are being fitted, driving the propeller through a speed-reducing gear. The engine is run at constant speed by using a controllable pitch propeller to vary the ship's speed. With these engines considerably stiffer mountings can be used but even so elaborate arrangements must be made to accommodate the thrust from the propeller and to minimise engine movements when the ship is gyrating in a heavy sea. As with resiliently mounted land installations care must be taken with the flexibility of external piping and other systems, but the problems are even greater on board a ship.

With a steam ship the main engine excited vibration problems are not so bad as with a motor ship, but on both types of ship the problem of propeller excited vibration must be seriously considered. If one envisages a five-bladed propeller six metres in diameter, and rotating at 150 rev/min, throwing large lumps of water at the hull and rudder 750 times a minute, some idea of the magnitude of the problem can be visualised. A lot of model and full scale research has been undertaken on this aspect of ship vibration alone, but there is still difficulty in predicting the effects with a new class of ship.

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The foregoing are the main causes of vibration on a ship, and these vibrations are mainly at low frequencies. They are therefore very effective at causing fittings to rattle and thus creating a noise problem as well. A number of other engine room items, such as electricity generating plant, pumps, and boiler fans, also create high noise levels but, by the judicious use of resilient mountings and other noise control devices, this noise can be kept mainly within the engine room.

Air-conditioning plant can not only create a noise problem in the spaces it serves but it can also cause a problem on recreation decks and on the navigating bridge.

Transmission of noise and vibration

With land work it is a common complaint that buildings are being constructed of lighter weight materials and yet noise control is expected to be better. The situation is similar in the marine world where shipbuilders are constantly seeking to reduce the deadweight of a ship whilst maintaining its strength. Over the last twenty years considerable weight savings have been made by reducing the cross sectional area of rolled steel sections, by scalloping out low load bearing webs, and by reducing the thickness of items such as deck plating. At the same time ship speeds have been increased - and power is proportional to the cube of ship's speed - with the result that more power is being transmitted by a lighter hull. Since the 1939/45 war most ships have beeen welded instead of riveted and this has reduced the hull damping coefficient (for low frequencies) by a factor of about two.

On a few smaller ships the superstructure containing the accommodation has been resiliently mounted on the main hull, and this has been very successful acoustically. As with the mounting of main and auxiliary machinery great care must be taken to restrain the motion in heavy seas, and facilities must be incorporated to enable the resilient mountings to be regularly inspected and, if necessary, changed. Unless suitably protected natural rubber can easily be adversely affected by seawater or sunlight. Although it is theoretically possible it is not practically expedient to resiliently mount the superstructure on a large ship. As with land practice it is possible to 'float' a cabin or other compartment within the ship's structure but, even more so than on land, the cost of this exercise goes against its regular adoption.

The exhaust systems of main and auxiliary diesel engines can cause a problem as their high temperature contents also contain considerable acoustic power - possibly at very low frequencies. If this acoustic power is not to be transmitted to the hull care must be taken to ensure that all points of attachment are sufficiently resilient and will not be damaged by the high temperatures.

Allowable noise and vibration levels

Quite a few countries, including the U.K., now exercise some form of control over the maximum noise levels permitted in various parts of a ship, but there are very few recommendations on vibration levels except where these affect machinery performance. In 1978 the Department of Trade issued a "Code of practice for noise levels in ships" which recommends maximum noise levels. In a few years time a comprehensive review of the working of the code of practice will be made and the making of mandatory requirements will be considered. The code is primarily concerned with the effects of noise on seafarers and does not apply to passenger cabins and other spaces. The code is not applicable to private pleasure craft and fishing vessels, and only partially applicable to ships below 24.4 m in length.

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In the following sections this paper considers in more detail the noise and vibration environment in three principal areas of the ship - the navigating bridge, the engine room, and the accommodation.

Navigating bridge

In some ways being on the bridge of a ship can be likened to being in a motor car: instrumentation such as the speedometer and warning lights must function reliably, it is advisable to understand correctly the commands of the navigator, and warning signals from other vehicles need to be distinctly heard. On a modern ship's bridge the instrumentation is often very sophisticated with satellite navigation receivers, computing radar sets, doppler docking devices, facsimile receivers for weather pictures, and so on. As mariners tend to become more reliant on these devices it is essential that their performance is not degraded because of vibration or other causes. The writer well remembers one occasion when the gyro-compass had been affected by the severe vibration on the bridge and the ship, which was on automatic helm control, was about 45° off course. On another occasion printed circuit boards were working loose in the radio room.

The problem of understanding navigational instructions is not so great as on land as it is customary for helmsmen to repeat any orders which they are given but, even so, it is not unusual for the bridge air-conditioning to be shut down because its noise renders communication difficult. The D.o.T. code of practice recommends a maximum level of 65 dB(A) for the wheelhouse.

In conditions of poor visibility - not to be confused with night time when a ship's lights should be visible - it is essential for a look-out on a bridge wing to hear a weak whistle, for instance from a coaster, at a distance of about two kilometres. Under these conditions the ship's main engines should be running at slow speed and their noise output considerably reduced but auxiliary machinery, including ventilating fans, will most likely continue to run normally. On one car ferry the extract fan from the car deck had been positioned just aft of a bridge wing with a resultant noise level at that position of 82 dB(A), and naturally the ship-owner insisted on some alterations.

Engine room

In ship's engine rooms the land practice of a maximum 8-hour L_{eq} of 90 dB(A) without ear protection is generally adopted. Compared with a land plant room space is generally very restricted in a ship's engine room, especially on a motor ship; it is often difficult to obtain noise readings at the conventional one metre from the machine boundary. Because of this it is even more important than usual to incorporate noise control devices at the design stage. Care must also be taken to ensure that such devices will not hamper maintenance at sea, or that they can be easily removed - and put back. To increase the power from a given size of machine the majority of modern ships' diesel engines are supercharged, and the blowers are driven by turbines from the energy in the exhaust gases. Unfortunately the noise from these blowers contains high frequency pure tones at a high level, and attenuation to acceptable levels can easily result in an unacceptable degradation of hydrodynamic performance.

It is unusual to find ships' engine room noise levels of less than 90 dB(A), and with medium speed diesel engines 115 dB(A) is not uncommon. For this and other reasons it is normal practice these days to have an engine control room which is acoustically isolated from the machinery space and where the maximum recommended noise level is 75 dB(A).

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When supplying auxiliary machinery for a ship's engine room it is advisable to remember that the part of the deck on which it will be mounted may be sufficiently flexible for resonances to occur, especially with high speed machines (i.e. running at about 3500 rev/min). Conversely care must also be taken in the selection of any resilient mountings to ensure that resonance does not occur in conjunction with some other excitation such as propeller blade frequency.

Accommodation

As most Environmental Health Officers will agree a large number of people will start to complain if the noise level in their bedrooms exceeds 35 dB(A) and yet these same people will quite happily pay hundreds of pounds to go on a cruise and accept as normal a cabin noise level of 50 dB(A); only when levels are in excess of 60 dB(A) are complaints liable to be forthcoming. It is fortunate that human nature is so perverse because in any modern ship which sails in tropical waters the air-conditioning air flow is very high and, if lower levels were required, the ducting would take up even more space than it does now.

It is difficult to predict air-conditioning noise in cabins for a number of reasons. Firstly the sound power level of the noise source is not often known with any degree of accuracy, mainly because an air-conditioning unit is made to a special configuration for an owner. Then the ducting follows a very tortuous path through the ship as shown on ships drawings - and an even worse path when actually fitted because of the requirements of other services. At the cabin end of the ducting the reheat units and the adjustable terminals have questionable characteristics, and finally the cabin reverberation time is largely a matter of guesswork.

Inter-cabin noise can also be a problem because the equivalent of a 225 mm brick party wall would not be very popular with the naval architects. Lightweight partitions of varying complexity, which also have to satisfy very stringent fire tests, have been developed to partly overcome this problem, together with sensible arrangements of bathrooms, wardrobes, etc., as sound barriers. As distinct from the comparable situation on land there is also, generally, more respect for one's neighbour, as watchkeepers are liable to make their feelings known if they are kept awake when they are trying to get some sleep in an off-watch period.

A ship's engine room generally extends the whole height of the ship and accommodation is arranged around it. To minimise the transmission of the machinery noise to the accommodation various precautions are taken: access doors are located in air-locks which also perform the function of changing rooms or stair-wells; lockers, laundries, toilets, etc., are placed immediately adjacent to the engine room bulkhead and thus form a double layer 'skin'; and alleyways separate this structure from the cabins themselves. The transmission of exhaust noise through the structure has already been mentioned, but it must not be forgotten that a diesel engine exhausts through the funnel and the outlet noise can easily reach the accommodation; a suitable silencer will quite possibly have to tune out frequencies of the order of 10 Hz, and the diameter of the exhaust pipe is often greater than one metre.

More so than on land the combined effects of noise and vibration need to be considered, and attempts have been made to produce a combined noise and vibration criterion. This could be of particular advantage when accommodation is located close to the propeller because in this area not only are high vibration levels often experienced but there is also the possibility of high level cavitation noise.